120W SSPA System Design for S-Band Uplink Application

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Abstract: There is a trend to replace TWTA of SSPA in S-Band uplink application for satellite operation. KARI developed 120W full S-Band SSPA system in early 2004. This paper covers SSPA system design and its test results. Through tests, nominal gain of 57dB, gain stability of +/-1dB over frequency, and gain stability of +/-0.5dB over temperature were shown. IMD value of -16.5dBc, -19dBc were revealed in P1 and P3 output operations. With meeting specifications, 120W SSPA is expected to be used in operational S-Band uplink application.
Key words: SSPA, GAIN, STABILITY, UPLINK

1. Introduction

Tube-type amplifier like TWTA, Klystron has been widely used for S-Band uplink especially for satellite command and data upload in satellite ground system. However, there has been a trend to replace tube-type amplifier with SSPA due to its mature technology availability. Very high power SSPA system up to 1kW is commercially available in S-Band as COTS [1].

In general, SSPA has merits in linearity, stability, operation and maintenance over TWTA in nature while less efficiency is only drawback.

In Korea, domestic SSPA module has been applied in many PCS repeater system which operates in near 1.9GHz. This kind of domestic SSPA module has been verified as fully reliable through its long operation in application field therefore design and manufacturing technology of domestic SSPA supplier has been field proven [2].

Output power and operation frequency in SSPA in PCS repeater application is similar to that of S-Band uplink for satellite control. Nominal CDMA power of 5W is considered as channel power based on PAPR and is around CW 30W in case of 6dB PAPR. ITU defines S-Band uplink frequency range as 2025~2120MHz, which is near to PCS and IMT2000 application.

Satellite has very sensitive command receiving feature which normally shows about -110dBm of signal lock threshold. In KOMPSAT operation, normal uplink TWTA output is about 50W in 9M antenna system. For 50W uplink, satellite telemetry shows received signal strength of around -80dBm which means ample command carrier margins more than 30dB.

KARI ground station decided to develop 120W SSPA system to replace operational TWTA using domestic technology. This paper shows key specifications, interface, and test results.

2. System Development

KARI defined key system requirements in amplifier system focusing on practical core functionality. Electrical and mechanical interface was decided as compatible with existing operational TWTA system. Table 1 shows key specification.

Table 1. 120W SSPA System Specification

	Specification	Value
1	Frequency Range	2025~2120MHz
2	Nominal Gain	57dB
3	Gain Stability, Frequency/Temperature	+/-1dB
4	Output power, 1dB compression	51dBm
5	VSWR	1.5:1
6	3rd IMD @ 3dB backoff	20dBc
7	Mechanical Dimension	19", 5U
8	Thermal Control	Heat-sink, Fan
9	Operation temperature	-10 ~ +50 deg-C
10	Primary power	220V, 5A
11	Controls & Monitoring	Local & Remote
12	Remote control	RS232
13	Controls	Enable/Disable
14	Monitoring	Enable/Disable
		Over-power
		Temperature
		Output power
		Reverse DC power

For simplicity, output level adjustment capability was not considered in amplifier functional requirement but more than 30dB input dynamic range was considered in amplifier which means SSPA output power can be adjusted by controlling the input power of SSPA. Because most domestic SSPA supplier provides only amplifier module, KARI developed all other components as system integrator.

1) SSPA module

Core functional requirements for SSPA module was derived from table 1 and flowed down to domestic SSPA

module supplier, SEWON TELETECH [2].

Selected supplier performed tuning adjustment required for output power and operational frequency range for newly developed class-AB linear SSPA module for IMT2000.

All control and monitoring parameters, gain level had been tested before delivery.

Fig. 1 shows a SSPA module delivered by supplier.

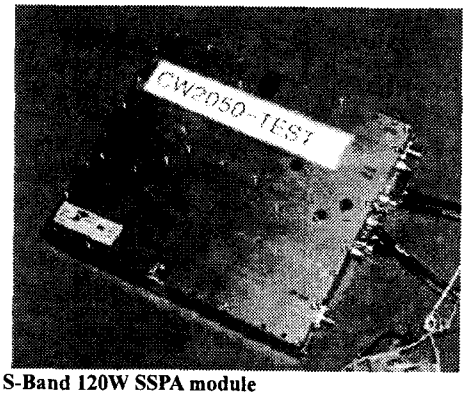

Fig. 1. S-Band 120W SSPA module

SSPA module provides 9-pin connector for control and status monitoring as shown in table 2.

Table 2. SSPA module I/O pin

Pin No	Function
1	GND
2	Over Power Alarm (Shutdown @52 dBm)
3	Reverse Power Alarm (@45 dBm ±2dB)
4	Temp Monitor
5	Over Temp Alarm (shutdown @85deg-C)
6	SSPA EN (Active Low : Enable , High : Disable)
7	Not Used
8	Forward Power Monitor (+4 VDC ±0.5 @ 51dBm)
9	Not Used

2) Controller

PIC 16F877-20/C was selected as microprocessor for controller and designed to have interfaces with LCD display hardware, enable/disable switches, LEDs, local/remote control selection switch. Crystal oscillator of 11.0592MHz was used as reference frequency.

Controller can control enable/disable through sending voltage signal to pin 6 in SSPA module and activate LED to show current status. Output power of SSPA is displayed in LCD display window by controller after determining output level from DC level of pin 8 in SSPA module through calibration curve.

All other information like over power alarm (pin 2), reverse power alarm (pin 3), temperature monitor (pin 4), over temperature alarm (pin 5) are interfaced with PIC through AD converter or directly.

5V DC power is provided by IC7805 from 9V DC power supplier.

PIC designed to handle all local and remote operation.

Controller interface diagram is shown in Fig. 2.

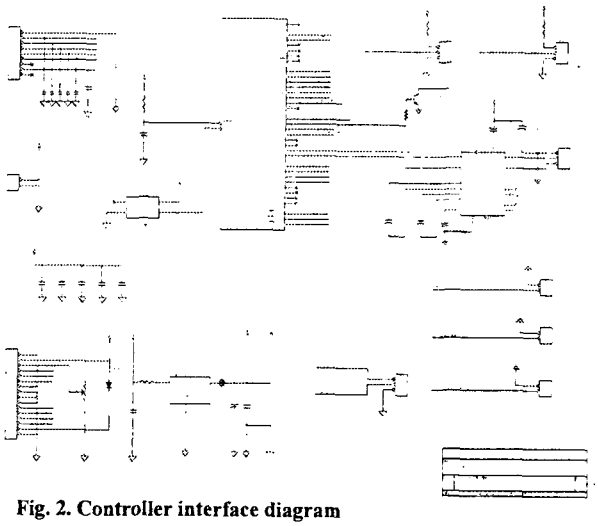

Fig. 2. Controller interface diagram

3) Message Format

RS232 interface was selected based on its simplicity and compatibility with operational interface. All data format consists of header, data, trailer and all data is ASCII. 1 bit of start, 8 bits of data, 1 bit of stop is used while no parity bit is used.

Table 3 shows control commands example.

Table 3. *Control commands*

Function	Code, Hex	ASCII
Enable	43 55	{CU}
Disable	43 4d	{CM}
Status polling	43 41	{CA}

Controller provides defined status message for each control commands. Status polling message leads long status data in response message including:

- SSPA output power level
- Temperature power alarm (0:OK, 1:NOK)
- Over power alarm (0:OK, 1:NOK)
- Reverse power alarm (0:OK, 1:NOK)
- SSPA module temperature
- Enable/Disable status (0:DIS, 1:EN)

Separate error message is designed for remote control mode when SSPA was selected in local mode by local front control.

4) Others

Mechanical design was completed with Korean company named APACK [3] especially for SSPA thermal control. Dedicate heat sink and fan assembly was provided for 24hr operation scenario. Selected DC power supplier for SSPA module is ESF600-28 from Fine

Suntronix [4]. 28V, 21A of 600W is provided from power supplier.

3. System Test

SSPA system has been fully integrated in KARI and tested. Gain test and IMD test were performed per each configuration. HP8648 signal generator, HP8562 spectrum analyzer, HP5437A power meter were used and celecom ccd011-2.05G/200-30A coupler was selected for 30dB coupler. Fig. 3 shows gain test configuration.

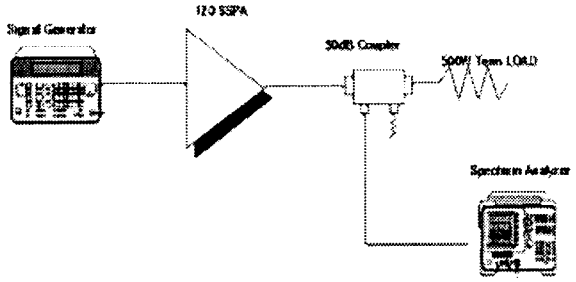

Fig. 3. Gain Test Configuration

Fig. 4 shows gain stability over input power range of –40 to –5dBm. Gain over input range variation shows the range of 55 to 58dB, which is applicable in output power adjustment varying the input power in small step size.

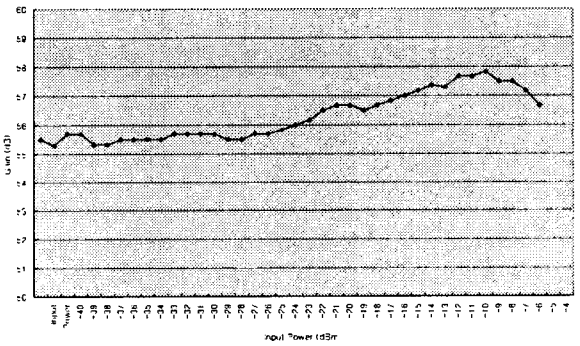

Fig. 4. Gain to input power variation

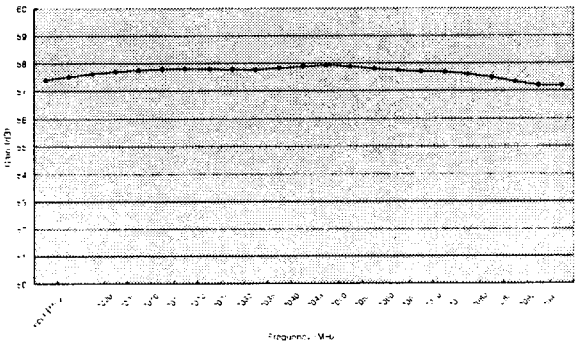

Fig. 5. Gain stability to S-Band frequency range

Fig 5 shows gain stability value of 57.5 +/-0.5 dB over full S-Band frequency range. Table 4 shows gain performance is stable over 30 to 65 deg.

Table 4. Gain Stability to temperature range

Temperature	Att	Output [dBm]@power Mtr	Real out	Gain [dB]
30	44	8.39	52.39	57.39
35	44	8.41	52.41	57.41
40	44	8.47	52.47	57.47
45	44	8.48	52.48	57.48
50	44	8.49	52.49	57.49
55	44	8.46	52.46	57.46
60	44	8.44	52.44	57.44
65	44	8.41	52.41	57.41

Fig 6 shows two-tone IMD test configuration. Test results for IMD in 1dB, 3dB-backoff are in Table 5, 6.

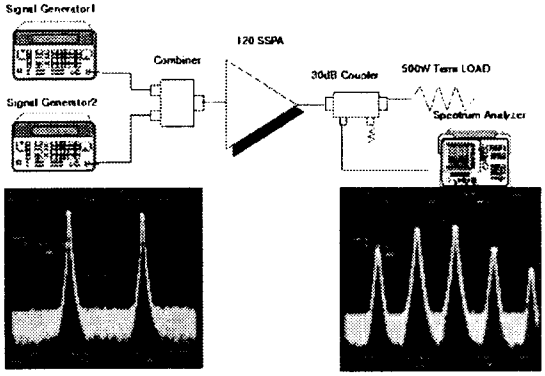

Fig. 6. Two-tone IMD test configuration

Table 5. Test Results in IMD test (1dB back-off)

	f1	f2	f1=2076, f2=2078 MHz
Carrier Output Power [dBm]	51	51	dBm/Tone input, -5.9 dBm
Fundamental [MHz]	2076	2078	
Harmonic [MHz]	4152	4156	2fo
	12456	12468	3fo
2nd IMD [MHz]	-2		f1-f2
	4154		f1+f2
3rd IMD [MHz]	2074		2f1-f2
	6230		2f1+f2
	2080		2f2-f1
	6232		f1+2f2
3rd IMD Power [dBm]			
2f1-f2	34.5		measured, dBm
2f2-f1	34.5		measured, dBm
f1, f2 Power	51		measured, dBm/tone
IMD [dBc]	16.5		f1-(2f1-f2) or f2-(2f2-f1)
OIP3[dBm/tone]	59.25		f1+(IMD/2)
IIP3 [dBm/tone]	1.75		OIP3-GAIN
Gain [dB]	57.5		

Table 6. Test Results in IMD test (3dB back-off)

	f1	f2	f1=2076, f2=2078 MHz
Carrier Output Power [dBm]	51	51	dBm/Tone input, -5.9 dBm
Fundamental [MHz]	2076	2078	
Harmonic [MHz]	4152	4156	2fo
	12456	12468	3fo
2nd IMD [MHz]	-2		f1-f2
	4154		f1+f2
3rd IMD [MHz]	2074		2f1-f2
	6230		2f1+f2
	2080		2f2-f1
	6232		f1+2f2
3rd IMD Power [dBm]			
2f1-f2	29		measured, dBm
2f2-f1	29		measured, dBm
f1, f2 Power	48		measured, dBm/tone
IMD [dBc]	19		f1-(2f1-f2) or f2-(2f2-f1)
OIP3[dBm/tone]	57.5		f1+(IMD/2)
IIP3 [dBm/tone]	0.7		OIP3-GAIN
Gain [dB]	57.5		

IMD value shows 16.5dBc and 19.0dBc in 1dB back-off and 3dB back-off operation, respectively.

All control and status monitoring function were successfully verified to be fully functionally acceptable in local control and remote control mode.

4. Conclusion

The overall description of 120W SSPA system developed for S-Band application was covered in this paper.

120W SSPA module had been tuned for S-Band uplink frequency range and output power from repeater application amplifier.

Amplifier shows gain stability of 57dB +/-1dB over frequency range and 57dB +/-0.5dB over temperature range. IMD values in P1 and P3 output operation are –16.5dBc and –19.0dBc, respectively.

All functional test results are acceptable to be used in S-Band uplink application. KARI plans to use 120W amplifier as backup for operational TWTA in 9m antenna system.

References

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